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The intra-examiner reliability of manual muscle testing of the hip and shoulder with a modified sphygmomanometer: a preliminary study of normal subjects

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The purpose of this study was to investigate the intra-rater reliability of manual muscle assessment of the hip and shoulder using a modified sphygmomanometer. In addition, it was intended to establish a preliminary database of values from normal, healthy male and female volunteers. Eighty subjects participated in the test sessions, 40 males and 40 females between the ages of 19–22. Forty subjects participated in each of the hip and shoulder test sessions. Each examiner tested different paired movements on the subjects in one single session for the two separate joints. The tested movements consisted of hip extension, flexion and abduction and shoulder abduction, extension, flexion, internal and external rotation. All movements were tested by the patient-initiated method. Each movement was repeated twice, with a 30–35 second rest interval between the trials. The results showed that the intratester reliability coefficients for the hip ranged from 0.94–0.97, while, for the shoulder, the range was 0.86–0.97. Norms are expressed as mean (SD) values. These data conformed to previously established expectations, in that side-to-side differences were less than 10% and test values for males were larger than females in all tests. It was concluded that manual muscle assessment using a modified sphygmomanometer has acceptable intra-examiner reliability for the hip and shoulder when using the patient-initiated method.
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Cette étude avait pour but d'examiner la fiabilité intra-évaluateur de l'évaluation musculaire manuelle de la hanche et de l'épaule à l'aide d'un sphygmomanomètre modifié. De plus, elle visait à mettre sur pied une base de données préliminaire renfermant des valeurs obtenues chez des volontaires masculins et féminins normaux et en bonne santé. Quatre-vingts sujets ont pris part aux séances de tests : quarante hommes et quarante femmes, âgés de dix-neuf à vingt-deux ans. Quarante sujets ont participé à chacune des séances de tests de la hanche et de l'épaule. Chaque examinateur a vérifié, pour chaque articulation, différents mouvements appariés effectués par les sujets au cours d'une seule séance. Ces mouvements comprenaient l'extension, la flexion et l'abduction de la hanche, de même que l'abduction, l'extension, la flexion et la rotation intérieure et extérieure de l'épaule. Tous ces mouvements ont été vérifiés à l'aide de la méthode de testage à l'initiative du sujet. Chaque mouvement a été exécuté deux fois, avec un temps de repos de trente à trente-cinq secondes entre les essais. Les résultats ont démontré que les coefficients de fiabilité intra-évaluateur variaient pour la hanche entre 0,94 et 0,97, tandis que dans le cas de l'épaule, l'écart se situait entre 0,86 et 0,97. Les normes sont exprimées en valeurs moyennes (ET). Ces données étaient conformes aux estimations établies précédemment. En effet, les différences entre les deux côtés étaient de moins de 10 % et les valeurs relevées chez les hommes étaient plus grandes que celles obtenues chez les femmes, et ce, pour tous les tests. L'étude a donc démontré que l'utilisation d'un sphygmomanomètre modifié pour l'évaluation musculaire manuelle procure une fiabilité intra-

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évaluateur acceptable pour la hanche et l'épaule lorsque la méthode de testage à l'initiative du sujet est employée. (JACC 1998; 42(2):73–82)

KEY WORDS: examiner, reliability, muscle, sphygmomanometer.

MOTS CLÉS : examinateur, fiabilité, muscle, sphygmomanomètre.

Introduction

Manual muscle testing is widely used in neuromusculoskeletal clinical practice as a method of determining muscle weakness.[1,2,3] Manual testing provides the examiner with diagnostic information as well as information about the baseline status of the patient's capabilities. It also enhances the ability of the clinician to assess the progress of an injured individual, by determining any improvements or deterioration in the condition of the injury.

Manual muscle assessment is a descriptive and subjective evaluation.[1,2] Consequently, an accurate assessment of muscle strength is often difficult to make, since there are a variety of intrinsic and extrinsic factors or variables involved in performing these studies.[4] For example, when different individuals are involved in the tests or when different techniques or instruments are used, the problem of reliability is compounded.[2,3]

In spite of these problems, several studies have been conducted in order to standardize the techniques and the type of instrumentation used.[3,5,6] It is well known that when different techniques are used by different examiners, some variations in the testing results can occur due to the examiners' training, experience, strength, and standards.[7,8,9] The use of standardized positions is also necessary in order to eliminate the variability that occurs due to body position and relative joint angles.[7] However, May found that there were no significant differences between the mean forces of hip abduction in the supine as opposed to the standing positions.[10]

The stabilization of the subject during the testing is also very important, since it has been shown to induce variability in the results.[11] The different instruments used for testing muscle strength have produced statistically reliable results under various conditions.[2,4,7,9,11–16] Because of this variability, specialized instruments, such as computer dynamometers, hand-held dynamometers, and cable tensiometers have been designed for clinical research and practice.[1,2,12–14]

Clinical studies have also shown that the general health of the subject, as well as the learning effect which is produced by repeated testings, have a significant influence on the results. Factors such as the effect of the motivation of the subject are somewhat more difficult to quantify or even eliminate.[2,4,14] The following factors have also been found to influence the testing results: pain in the testing areas, physical condition of the subject, instructions, patient's attitudes, feed-back of their results, competition between subjects, fear of the testing, as well as any type of incentives.[4,9] Kroll has shown that the schedule, i.e. the time of testing, can seriously affect the reliability of the test-retest technique to determine strength, and therefore he questions the validity of a test for assessing any improvements under therapeutic conditions.[15,16] He explained that the trial effect variable, which is the decrease in muscular performance or strength with repeated measurements, was due to the depletion of energy reserves owing to the lack of time the subject had to recuperate between trials.

Other studies also show that the testing procedures used for manual muscle testing involve a learning process for both the tester and the subject.[2,15,16] The more experience the tester has with the instrumentation, and the greater the familiarity of the subject with the movements to be tested, the greater the probability of reproducing consistent results.[2,15,16]

Manual muscle testing however, appears to be an acceptable procedure in patients with obvious muscular weakness,[1,17] but not for those cases in which the patient exhibits only mild muscle weakness.[1] Beasley has shown that a muscle which may appear to be testing normally, may only be performing at 50% of its normal value because of undetectable or partial damage to a muscle.[18]

A search of the literature, suggested that a study comparing the reliability of a single tester on normal subjects using a modified sphygmomanometer to test hip and shoulder function had not been performed. Consequently, we initiated this study to provide a set of values for normal male and female subjects between the ages of 19–22. A modified sphygmomanometer was chosen because it is a fast, efficient, and economical way of testing muscle strength. The objectives of this study were: a) to determine the intratester reliability of manual muscle testing using a modified sphygmomanometer; b) to develop a set of normal reference values using this instrument for a representative and clinically significant set of muscle activities; c) to test the null hypothesis that there were no significant differences between the test-retest measurements due to the tester; d) to test the second null hypothesis that there were no significant differences between the left and right leg measurements for a given movement.

Methods and materials

Subjects

Eighty normal student volunteers between the ages of 19–22 participated in this study. Of this group, 40 were male and the other 40 were female. The volunteers were required to meet the following conditions: 1) that they be in normal health, being described as having no physical pain and no current illnesses; 2) that they have had no prior injuries, especially in the extremities; and 3) no current orthopaedic problems. A questionnaire, which was used for screening the participants, also provided information on the basic research techniques and included a consent form. Forty subjects participated in each of hip and shoulder strength testing sessions.

Tester

Two testers, pre-clinical students with several hours of practice using the modified sphygmomanometer, were involved in this study, one for each joint area tested.

Instrument

The test instrument used in this study was a modified sphygmomanometer. The modification made to the sphygmomanometer or blood pressure cuff involved altering the position of the air tube and meter so they were both fixed on to the front of the cuff (provided by Dr. A. Schulte, personal communication). In conducting the test, the instrument was first pumped up to register 20 mm of mercury and the tester placed his left or right hand inside the cuff, depending on which limb and movement was being tested. A second modification was made to this device – a second one-way valve, which insured that no air was released from the cuff after pressure from the test was released. This had the effect of maintaining the needle position on the dial, so that an accurate measurement could be made. After each test, the pressure within the cuff was totally released before commencing the next test.

Movements tested

The following movements were tested: hip extension, hip flexion, and hip abduction and shoulder abduction, extension, flexion, internal and external rotation. Hip extension was tested in the prone position; for hip flexion, the subject was in the supine position; and for hip abduction, the subject was lying laterally recumbent. Shoulder tests were conducted with the subject seated on the end of the examining table. Each test involved measurements of both limbs. Subsequently, after a 30–35 second rest interval, each movement was retested. During the test procedure, stabilization of the subject's body was provided by the tester.

Testing procedures

All the tests were conducted between 11:30 a.m. and 12:30 p.m. This time period was chosen since it seemed that some of the subjects could be suffering from the effects of a lack of sleep if the testing was done too early in the morning, or, conversely, if the tests were conducted in the evening some individuals may have been involved with activities which induced muscle fatigue. Either one of these factors could have affected the test results.

Prior to each test, the subject was briefed on how the movements were to be performed. Subsequently, the subject was allowed to practice the motions before the actual testing was done. The testing sequence of the three hip and five shoulder movements was randomized to control for an order effect. The "break" test method of measuring the pressure exerted was used. In this method the tester pushes against the subject's maximal attempt to exert a movement by contraction of a muscle group.[19] The subject initiates the force and the examiner responds in kind.

In order to reduce the impact of variability due to different surface contacts, all test sites were comprised of flat muscular surfaces of the mid-to-lower thigh and the upper arm. No sites with boney prominences were selected, and, as such, the interfaces between the pressure cuff and the body test sites were relatively equivalent between different tests, different limbs and between different subjects. A 30–35 second rest interval was alloted between the initial test and the second test or retest.

All of the tests were conducted on a table having the following dimensions: 152 cm long, 61 cm wide, and 76 cm in height. The size of the table allowed the subject to lie or sit comfortably and also permitted the tester to lean over the subject, thus enabling the tester to adjust or react to each individual subject, such as by applying more resistance to stronger subjects.

The procedure for the hip extension test involved laying the subject in a prone position. Next, the subject was told to lay his/her hands to their sides, without holding on to the table. In order to test the right leg, the tester stood on the right side of the subject. The tester placed the cuff on his right hand and positioned the hand just above the back of the knee, resting it on the semitendinosus and the long head of the biceps femoris of the hamstring muscle group. To start the test, the subject was asked to bend the leg to almost a 90 degree angle and raise the thigh 15–20 degrees off the table (Figure 1). The subject then initiated the action by pushing straight up, using a hip motion and not a knee motion. The tester resisted with an increasing downward pressure until equilibrium was reached and the pressure exerted by the subject was then recorded. The subject was allowed to relax for 30–35 seconds and the procedure was repeated on the same leg. Subsequently, the contralateral leg was tested in the same manner.

The procedure for the hip flexion test involved positioning the subject in a supine position. The subject was told to place his/her hands on their stomach and to rotate the foot of the leg being tested, 45 degrees outwards from the body. In order to test the left leg, the tester stood on the left side of the subject, and the modified sphygmomanometer, which was placed on the right hand, was then positioned just above the inside of the knee, resting on the vastus medialis muscle. The subject was also informed not to sway when executing the test or to hold on to the edge of the table. The test was initiated by instructing the subject to raise his/her leg 25–30 degrees vertically off the table and then to initiate the action by pushing their leg up and outwards (Figure 2). Meanwhile, the tester resisted the subject by pushing down and out with his right hand. When the equilibrium point was reached, i.e., when the subject could no longer push any harder against the tester, a measurement on the sphygmomanometer was taken and recorded. The subject was then allowed to relax for 30–35 seconds before a retest of the same leg was conducted and a second measurement obtained in a similar manner. Subsequently, testing was conducted on the opposite leg, using the opposite hands for stabilization and testing.

The test for hip abduction (Figure 3) was conducted with the subject lying on his/her side. The subject's free or upper hand was placed in a comfortable position on their side while the lower one was used to prop up their head or it was bent so the head can be placed on the inside of the elbow. In order to test the left leg, the tester stood behind the subject at about the mid thigh. With the subject's shoulders and pelvis perpendicular to the table, the subject's right leg was bent in a 45 degree angle while holding their left leg straight out over the right leg. The tester, having placed the cuff on the right hand, now positioned it on the vastus lateralis muscle, just above the knee. The test was started by having the subject first raise the left leg 15–20 degrees straight up, and was then told to initiate the action by pushing straight up while the tester resisted this action with pressure downwards until the equilibrium point was reached. The pressure exerted on the cuff was then recorded and the subject relaxed for 30–35 seconds before the second test was performed. The right leg was tested in the same manner, with the tester holding the sphygmomanometer in the opposite hand.

The procedure for shoulder abduction was as follows. The start of the test (Figure 4) involved the subject beginning with their arm extended at approximately a 35 degree angle to the vertical in the coronal plane. The tester's right hand was placed into the sphygmomanometer, and it was placed half way up the forearm. The tester stood behind the subject which allowed for a stable and effective counter force to be provided. The tester then told the subject that the test can begin and the subject gradually provided an increasing force upward in the coronal plane until the maximum was achieved. This number was then recorded

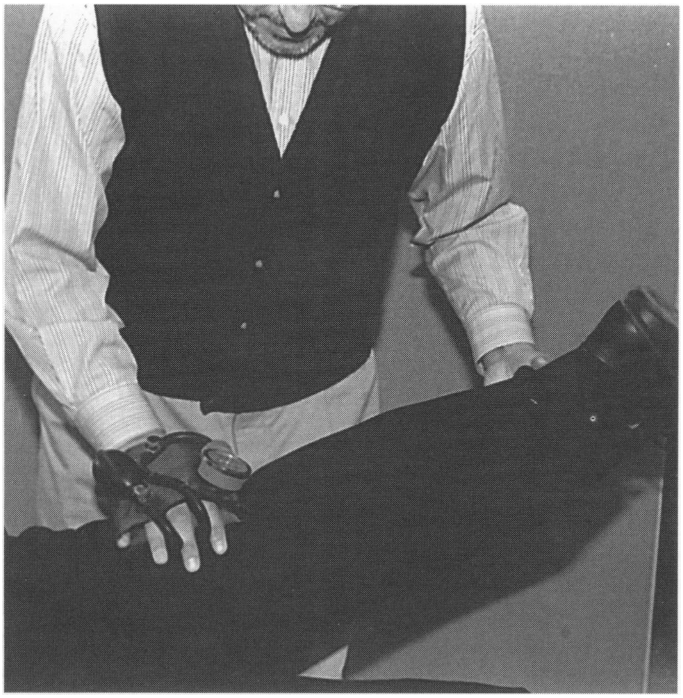

Figure 1 Hip extension.

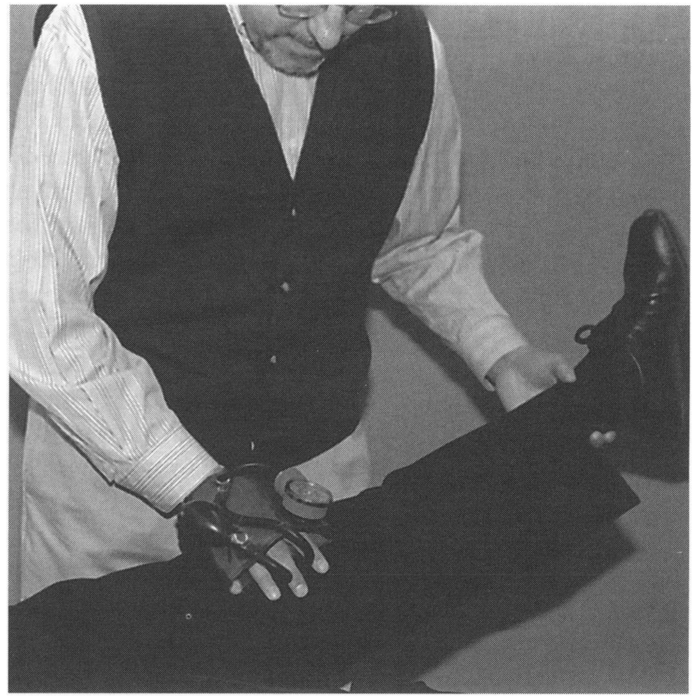

Figure 2 Hip flexion.

Figure 3 Hip abduction.

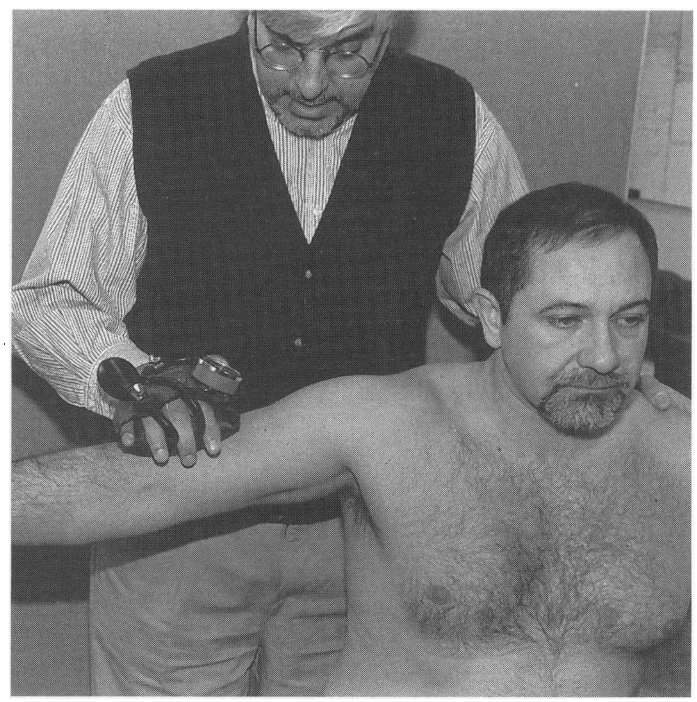

Figure 4 Shoulder abduction.

on the data sheet and the next test was performed 15 seconds later.

The procedure for shoulder extension started with the subject sitting upright with their arm in approximately a 20 degree angle to the vertical in the median plane (Figure 5). The sphygmomanometer was placed above the elbow on the inside of the forearm. The tester stood in a position behind the subject with the left hand on the subjects right shoulder for stabilization. The test began and the subject pushed backwards in the median plane until the maximal force was reached.

Flexion was tested in the following manner. With the subject sitting upright the right arm was extended forward in the median plane to a 30 degree angle from the vertical (Figure 6). The sphygmomanometer was placed on the forearm above the elbow. The left hand of the tester was placed on the left shoulder of the subject for stabilization. When the test was started the subject pushed upwards in the median plane until a maximum force was reached.

The procedure for internal rotation began with the subject sitting upright with their right arm bent 90 degrees at the elbow, in the median plane (Figure 7). It was explained that the elbow is the pivot point and that the force is to be provided in the horizontal plane towards the inside of the body. The left hand of the tester was situated on the left shoulder of the subject to ensure that the proper pivot point and movement was being performed.

The procedure for external rotation involved the same starting position as internal rotation for the subject. The sphygmomanometer was placed above the outside of the wrist while the tester was standing on the right side of the subject with their left hand on the left shoulder for stabilization (Figure 8). The elbow was the pivot point and the movement was in the horizontal plane to the outside.

Data analysis

The test for association between means of matched pairs, or the Intraclass Coefficient, was used in order to confirm the first null hypothesis, "i.e." that there were no significant differences between the repeated measurements (level of significance was set at 0.05). The Students' t test was used to validate the second null hypothesis, "i.e." that no differences existed between measurements for males as compared to females for each test (level of significance was set at 0.05).

The means and standard deviations were calculated for each combination of movement, sex, and trial.

Results

Tables 1 and 2 represent the means and standard deviations for each combination of movement, sex and trial for the hip and shoulder respectively. These tables also show the t-stat values for male vs female measurements. The results indicate consistently and statistically significantly higher values for males as compared to females.

The results of the Intraclass Correlations are shown in Tables 3 and 4. They reveal a strong association between paired trials, allowing for acceptance of the first null hypothesis.

Percentage comparisons for side-to-side, male-to-female and test-to-test values are shown in Tables 5 and 6.

Discussion

During the past several decades, considerable interest has been focused on muscle testing by various groups of investigators.[1–3,13] The nature and scope of the studies range from attempting to assess the degree of muscular dysfunction or neuromuscular impairment to the analysis and evaluation of human muscular performance.[3,11,12,18] The information obtained from these studies is of interest not only to physiologists and kinesiologists, but also to professionals in clinical settings.

This current study was undertaken to 1) examine the intratester reliability of performing muscle testing of the hip and shoulder using a modified sphygmomanometer device, and, 2) to establish a preliminary database of values on normal, healthy male and female volunteers. It has been found that this instrument is very reliable for manually measuring muscle strength when the patient-initiated method is utilized. This method has also been used by Hsieh and Phillips in conjunction with a computerized, hand-held dynamometer.[1] The test procedure in each case also incorporated the "break" method of testing, a technique which has been shown to be quite dependable.[1] Reported reliability of the "break" test method in the literature ranged from 0.87[10,11] to 0.95[12] for hip abduction, 0.74[13] to 0.97[11] for hip flexion, and 0.90[12] to 0.96[11] for hip extension. In this study, values ranged from 0.94–0.97 for hip abduction, 0.97 for hip flexion, and 0.94 for hip extension, when testing left and right legs in one session, and from 0.86–0.97 for the shoulder. This suggests that our results are comparable to those of other investigators. The

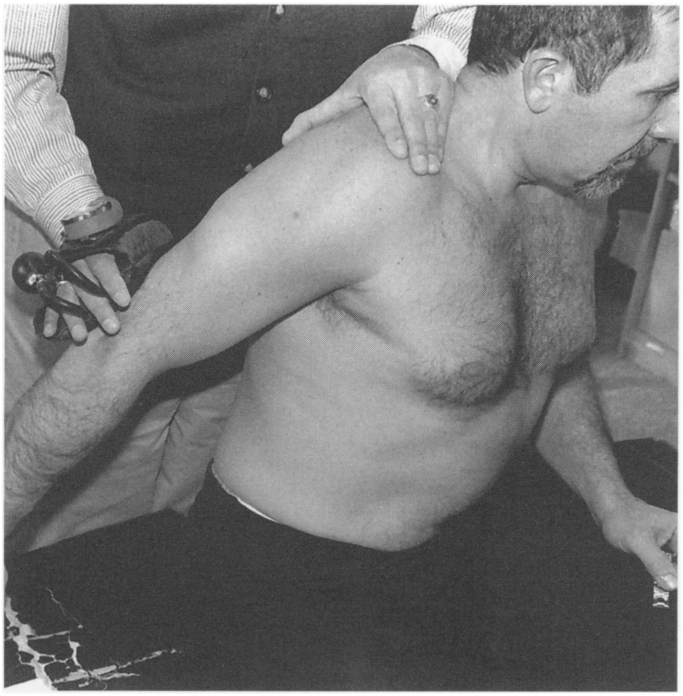

Figure 5 Shoulder extension.

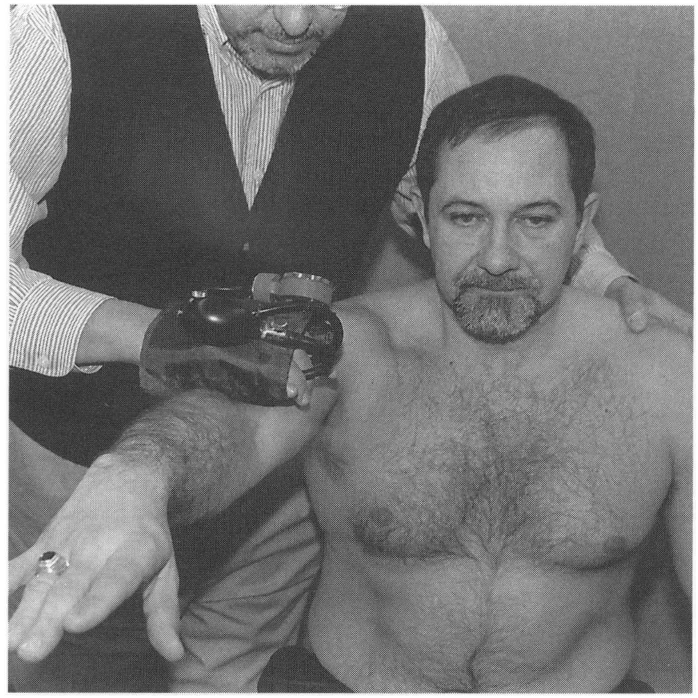

Figure 6 Shoulder flexion.

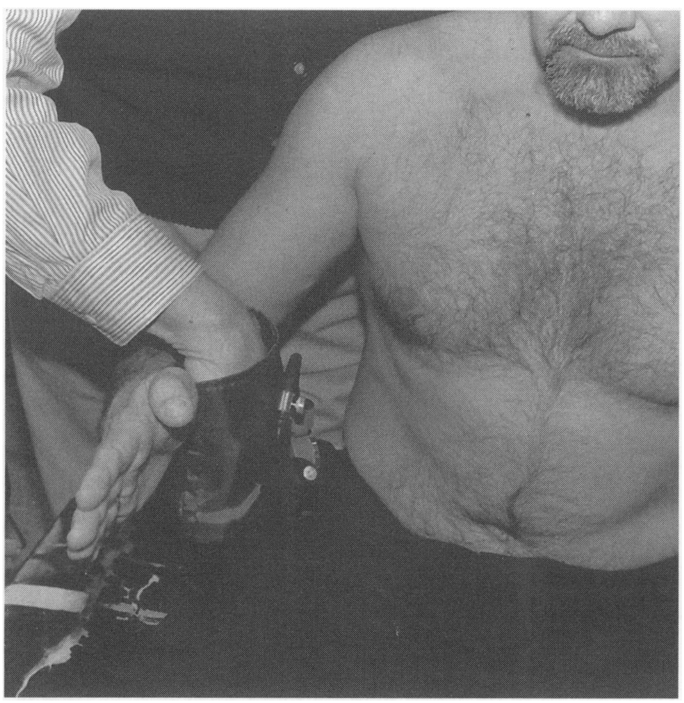

Figure 7 Shoulder internal rotation.

Figure 8 Shoulder external rotation.

Table 1
Mean (SD) Values for Hip Tests: Males vs Females (in mm Hg)

Movement	Males	Females
Left Abduction	312.4 (41.7)*	223.5 (37.4)
Right Abduction	299.4 (40.7)*	226.8 (41.5)
Left Extension	210.3 (30.2)*	161.0 (33.3)
Right Extension	218.4 (38.9)*	169.6 (32.3)
Left Flexion	283.3 (36.7)*	198.1 (35.6)
Right Flexion	296.5 (40.7)*	208.9 (39.3)
* (male vs female, $p \leq 0.0001$)		

Table 2
Mean (SD) Values for Shoulder Tests: Males vs Females (in mm Hg)

Movement		Males	Females
Abduction	L	134 (20)*	92 (11)
	R	140 (23)*	99 (13)
Flexion	L	141 (26)*	99 (15)
	R	150 (25)*	102 (15)
Extension	L	144 (22)*	134 (20)
	R	132 (24)*	140 (23)
Int. Rotation	L	182 (44)*	117 (23)
	R	190 (52)*	122 (28)
Ext. Rotation	L	144 (26)*	101 (17)
	R	137 (23)*	99 (13)
* (male vs female, $p \leq 0.0001$)			

Table 3
Intraclass Coefficients (Hip)

Movement Tested	Intraclass Correlation Coefficient	
	Males	Females
Left Abduction	0.964	0.901
Right Abduction	0.904	0.967
Left Extension	0.901	0.903
Right Extension	0.913	0.891
Left Flexion	0.931	0.916
Right Flexion	0.919	0.943

Table 4
Intra-class Coefficients (Shoulder)

Movement	ICC Value
Left Abduction	0.94
Right Abduction	0.95
Left Extension	0.93
Right Extension	0.94
Left Flexion	0.87
Right Flexion	0.95
Left Internal Rotation	0.94
Right Internal Rotation	0.97
Left External Rotation	0.86
Right External Rotation	0.93
AVERAGE	**0.93**

majority of these examiners used a 4–5 second “break” session to test each movement, i.e. the duration between the onset of maximal muscle contraction and the time of recording the measurement. In contrast, we used a shorter “break” session of 2–3 seconds, identical to that employed by Hsieh and Phillips.[1]

For any test procedure to be considered completely reliable, there should be no variation in the values of the test-retest measurements. The correlation coefficients from this study ranged from 0.86–0.97. This compares favourably with the intratester reliability coefficients of 0.96–0.99 obtained by Hsieh and Phillips.[1] Bohannon and Andrews, in their study using a hand-held dynamometer, reported reliability factors of 0.84–0.90.[19] Since no comparable reports involving the use of a modified sphygmomanometer could be found in the literature, di-

Table 5
Percentage Comparisons (Hip)

Movement		Males vs Females	Male	Female
Abduction	L	28		
	R	24		
L vs R			4	1
Flexion	L	30		
	R	30		
L vs R			4	5
Extension	L	23		
	R	22		
L vs R			4	5
Combined Flex vs Ext			+ 35	+ 23
Combined Abd vs Ext			+ 43	+ 36

Table 6
Percentage Comparisons (Shoulder)

Movement		Males vs Females	Male	Female
Abduction	L	46%		
	R	41%		
L vs R			6	3
Extension	L	7		
	R	(6)		
L vs R			8	4
Flexion	L	42		
	R	47		
L vs R			6	3
Int. Rotation	L	56		
	R	56		
L vs R			4	4
Ext. Rotation	L	43		
	R	36		
L vs R			5	2

rect comparisons with other similar studies using the same instrument could not be made.

However, it is apparent that studies of this nature have a number of limiting factors in so far as obtaining accurate and consistent results. These factors, according to Hsieh and Phillips, include the following: the subjects used in the study, the tester, the instrument, the testing procedure, the time of testing and the environment.[1]

Bohannon and Andrews also explained that the low values of their reliability coefficients may have been due to the type of instrument employed and the level of experience of the tester.[19] Their study also consisted of performing test-retest measurements with a hand-held dynamometer, using a 4–5 second "make" method in order to determine the intertester reliability. The "make" method differs from the "break" method of testing in that the former involves holding the dynamometer stationary while the subject exerts a maximal force against it.

According to Hsieh and Phillips, if the pre- and post-treatment measurements obtained in a clinical setting exceed the normal range of variation, the results can be considered valid.[1] This normal variation, for isometric testing conducted in a one day study, was reported to be between 5–15%.[1,2,13]

Another variable which can present a problem concerns the strength level of the tester. In a study undertaken by Marino et al., the strength level of the subject prevented the tester from obtaining accurate results from the manually tested muscle.[2] Hsieh and Phillips also reported that a few of their stronger subjects overpowered one of their testers.[1] In this study the patients were instructed to start exerting pressure slowly, so that the tester could remain overtop of the subject until the test was completed; thus overpowering the tester was not a problem.

Our data clearly indicated that there were significant differences between the strength measurements of males and females. Not surprisingly, the males are stronger than the females. Their results were consistent with the data obtained by Hsieh and Philips.[1]

Since past studies, involving isometric strength testing, have also shown that statistically significant differences can be observed when the testings are conducted at different times during the day,[4] in this study, all tests were performed between 11:30 a.m. and 12:30 p.m. Whether the selection of this time period was more efficacious than some other time remains equivocal.

Tables 5 and 6 show that the side-to-side differences ranged from 1–8%, with no gender differences. This is consistent with published findings from previous studies in the extremities and with bilateral spinal movements[1,4,20,21]. These tables also show that subjects are typically stronger in certain movements. The average values for hip abduction were larger than for flexion which were slightly larger than for extension. For the shoulder, the order of strength values differed between males and females. In males, internal rotation values were largest, while for females, extension was strongest. There is no apparent explanation for male vs female differences, while joint and muscle biomechanics likely explain the differences between muscles.

Conclusions

This study investigated a fast and efficient method of manually assessing muscle strength and, within the restrictions applied in this study, the modified sphygmomanometer was found to be a very reliable measuring device for hip and shoulder testing.

The intratester reliability coefficients, using the modified sphygmomanometer, ranged between 0.86–0.97 and, with further refinement of this technique, a clinician or researcher may be able to improve the relative values. Males were found to demonstrate consistently larger test values in all three muscle tests. It would appear that other studies of this nature should be undertaken using a modified sphygmomanometer and reliable baseline data on the strength of a variety of muscle groups can be developed. This type of information would be highly useful to various clinicians to compare and assess muscle strength or weakness.

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